Adaptive Channel Equalization for a Potential Airport Wireless Local Area Network

Minh Nguyen

Izabela Gheorghisor

April 26-29, 2004

Integrated Communication, Navigation and Surveillance Conference

F083-B04-010

Introduction

- The FAA is evaluating the feasibility of a high-speed wireless communication system to support mobile airport surface applications
  - 5.091-5.15 GHz band within the aeronautical radio navigation service (ARNS) band was considered
- Consider wireless local area network (WLAN) IEEE 802.11 as a candidate standard for airport applications

Why WLAN 802.11?

- Leverage the rapid proliferation of wireless local area network (WLAN) technologies (e.g., IEEE 802.11 a/b/g) and apply them to aviation
- These commercial technologies are currently used for broadband wireless Internet access on unlicensed bands
  - 5 GHz National Information Infrastructure and 2.4 GHz industrial, scientific and medical (ISM) band
- WLANs based on IEEE 802.11 b/g are deployed in the 2.4 GHz The lowest U-NII subband starts at 5.15 GHz, therefore is adjacent to the candidate band (5.091-5.15 GHz)
- Equipment cost is decreasing significantly due to widespread use of WLAN technologies

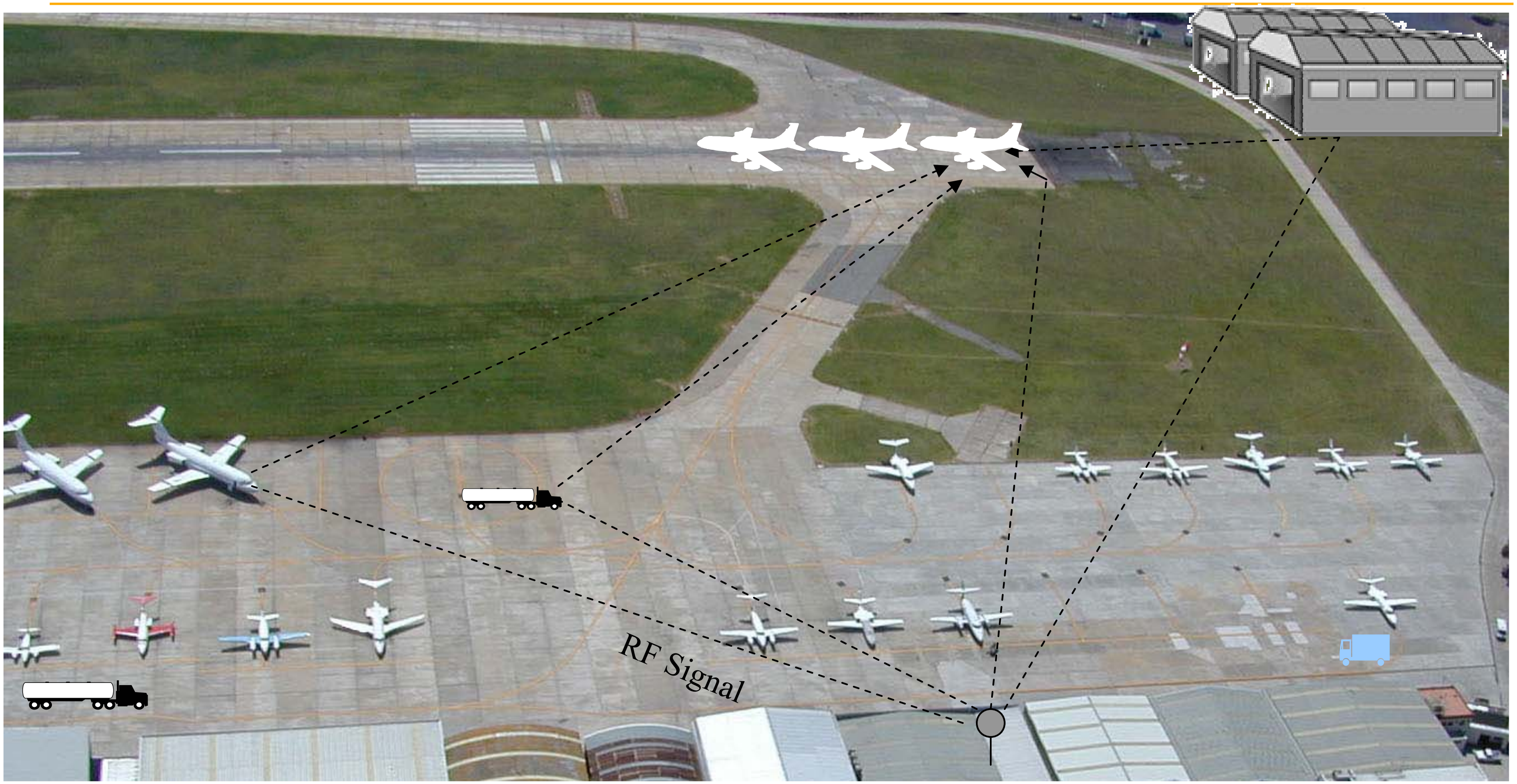
MITRE
CAASD

F083-B04-010

Doppler Effects in an Airport Environment

- Direct applicability of IEEE 802.11a to aviation use poses a challenge since most commercial devices have been designed primarily for stationary terminals (e.g., stationary users in offices, college campuses, and other public areas)
- Aircraft taxi on and off airport runways at a maximum speed of 40 miles per hour (mph)
  - Mobile environment compared to a typical WLAN environment
  - Doppler shift (300 Hz at 5 GHz) causes rapid changes in the radio channel dynamics (fade rate)
  - Doppler increases the chances of signal dropouts (30 dB or more of signal fade)

Multipath Effects in an Airport Environment

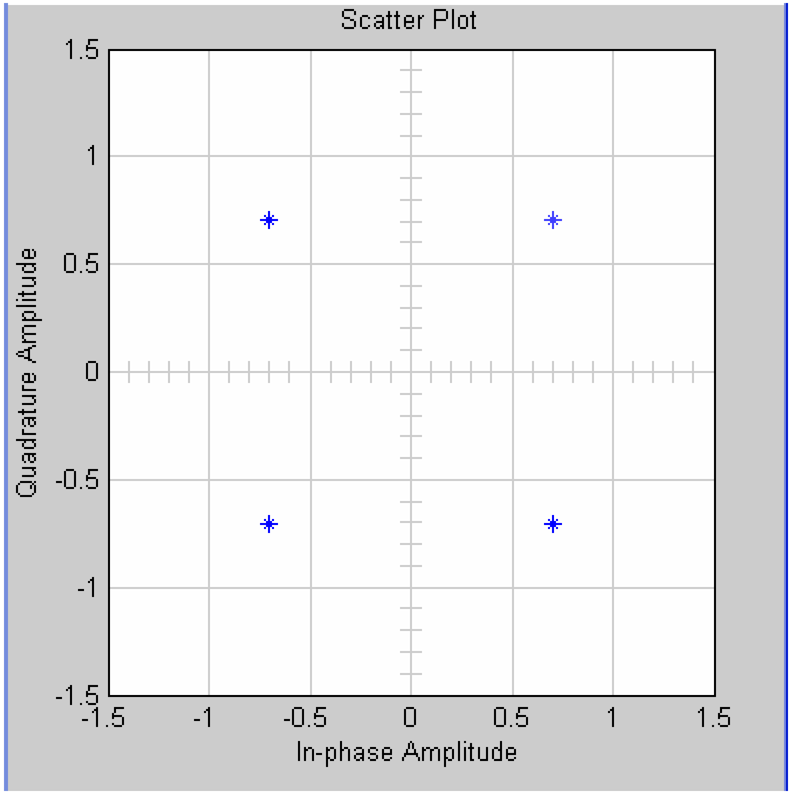


MITRE

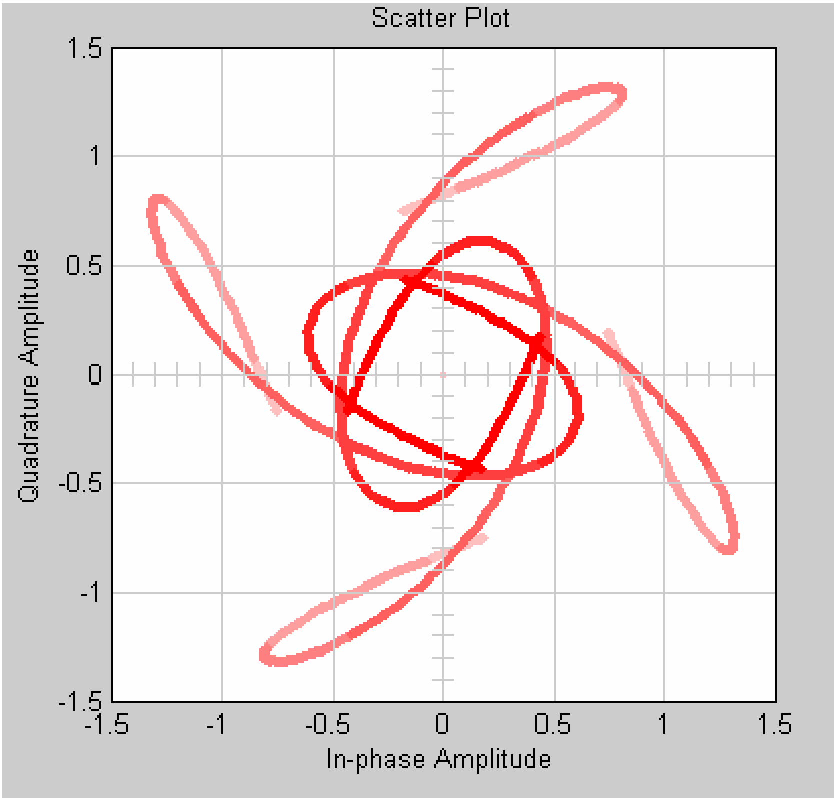
CAASD

F083-B04-010

Doppler and Multipath Effects on Signal Constellation



QPSK Transmit Signal Constellation



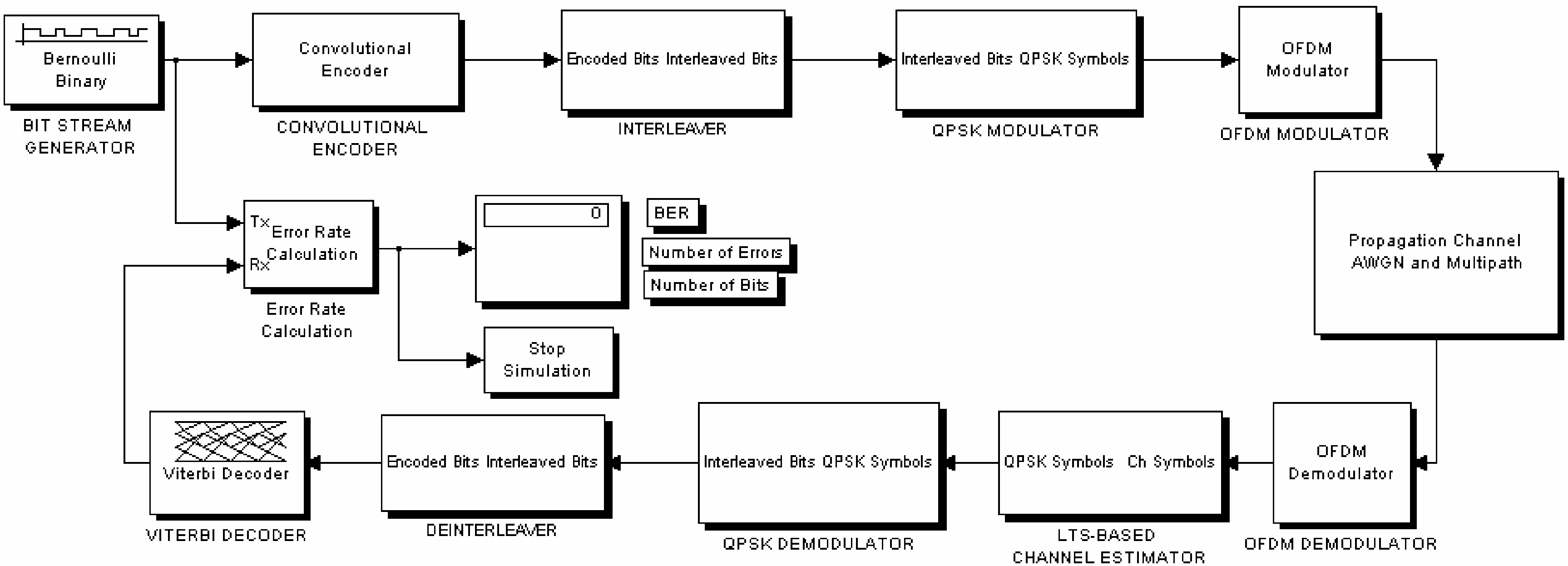
QPSK Signal Constellation Affected by Doppler and Multipath

F083-B04-010

Approach

- **Implement adaptive channel equalization to overcome the channel impairments caused by Doppler and multipath**
  - Use Matlab/Simulink for modeling and simulation
  - Consider a simple equalizer algorithm
    - Least Mean Square (LMS) equalization selected because it is a well-known technique which allows for practical implementation
- **Integrate the adaptive channel equalizer into an IEEE 802.11a model and evaluate its performance**

IEEE 802.11a Baseline Model

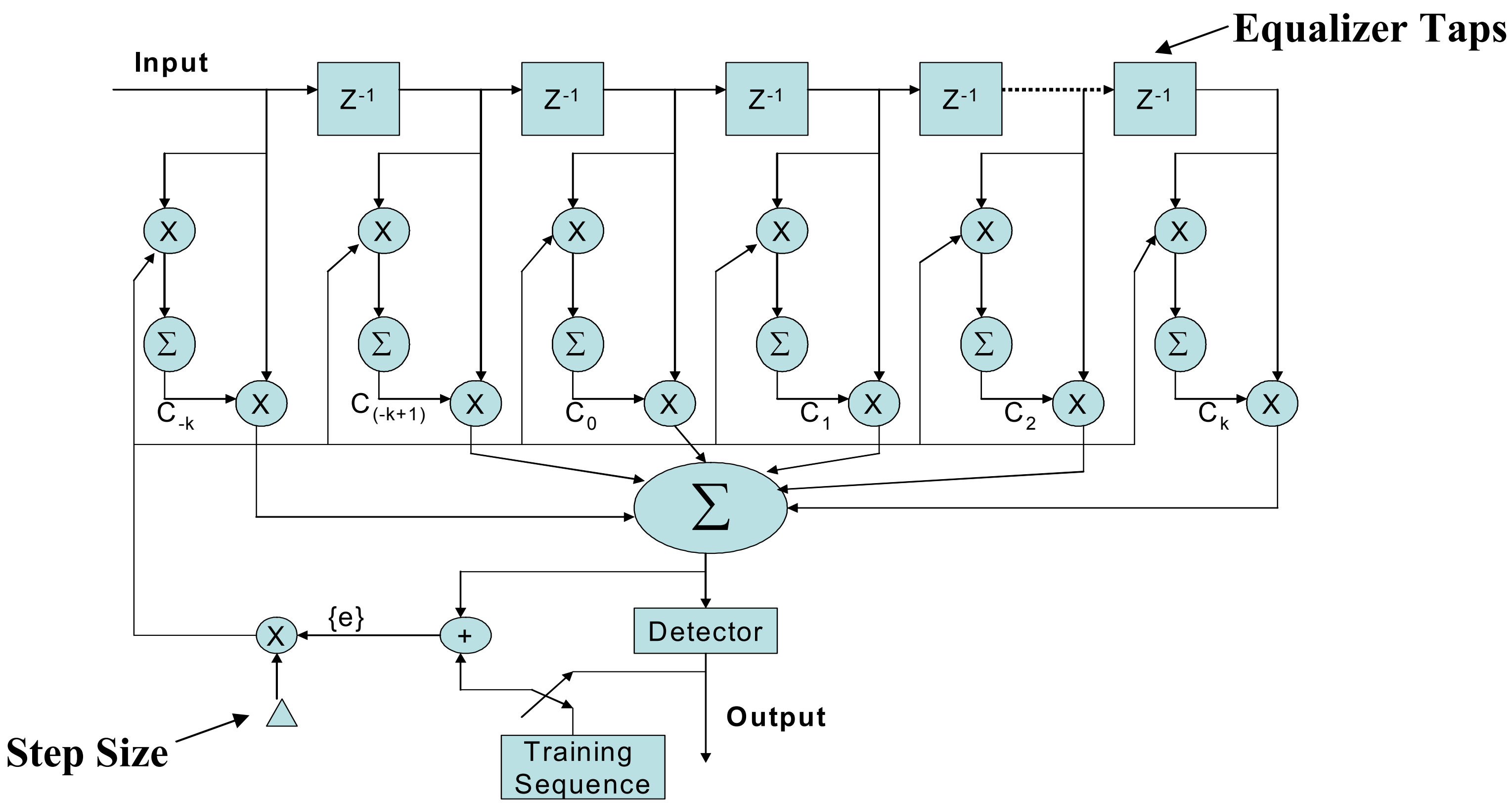


Data rate: 12 Mbps
Convolutional encoder rate: ½
Interleaving
Modulation: QPSK and orthogonal frequency division multiplexing (OFDM)
Channel estimation: Two OFDM symbols are used
Viterbi decoding: Hard decision decoding is used

MITRE CAASD

LMS Equalizer Block Diagram

LMS algorithm adapts to changing channel characteristics by recursively adjusting the tap weight coefficients (C_i) to reduce the average mean-square error

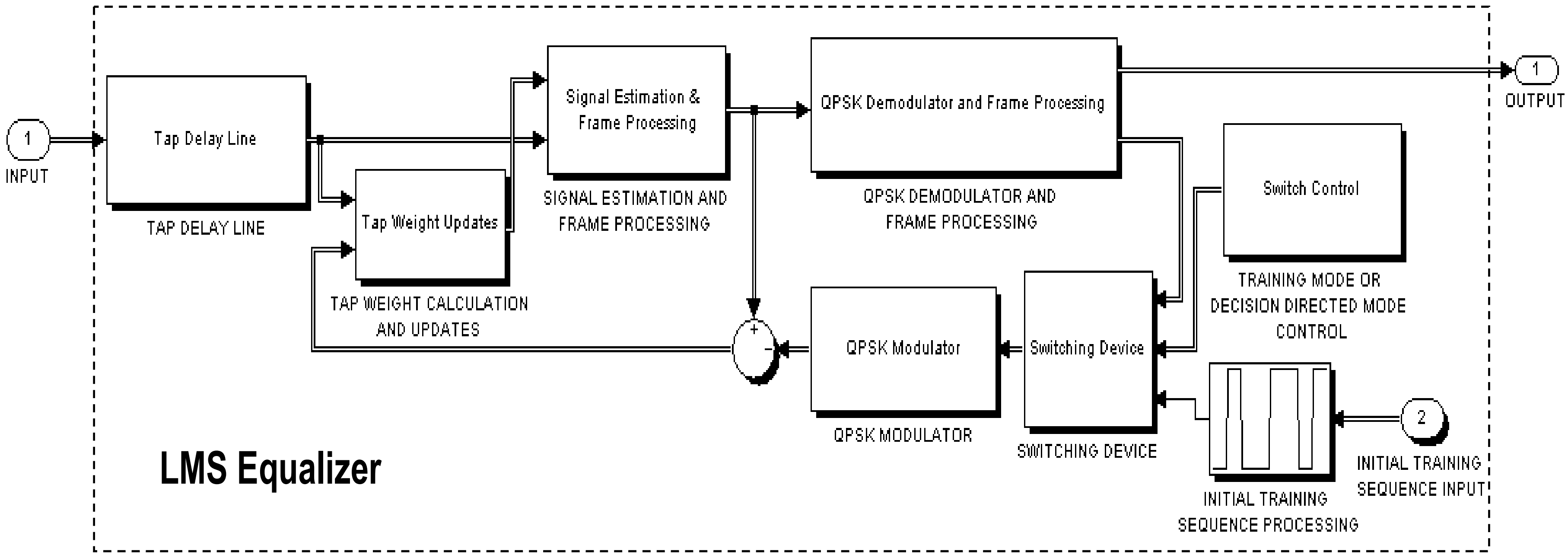


MITRE

CAASD

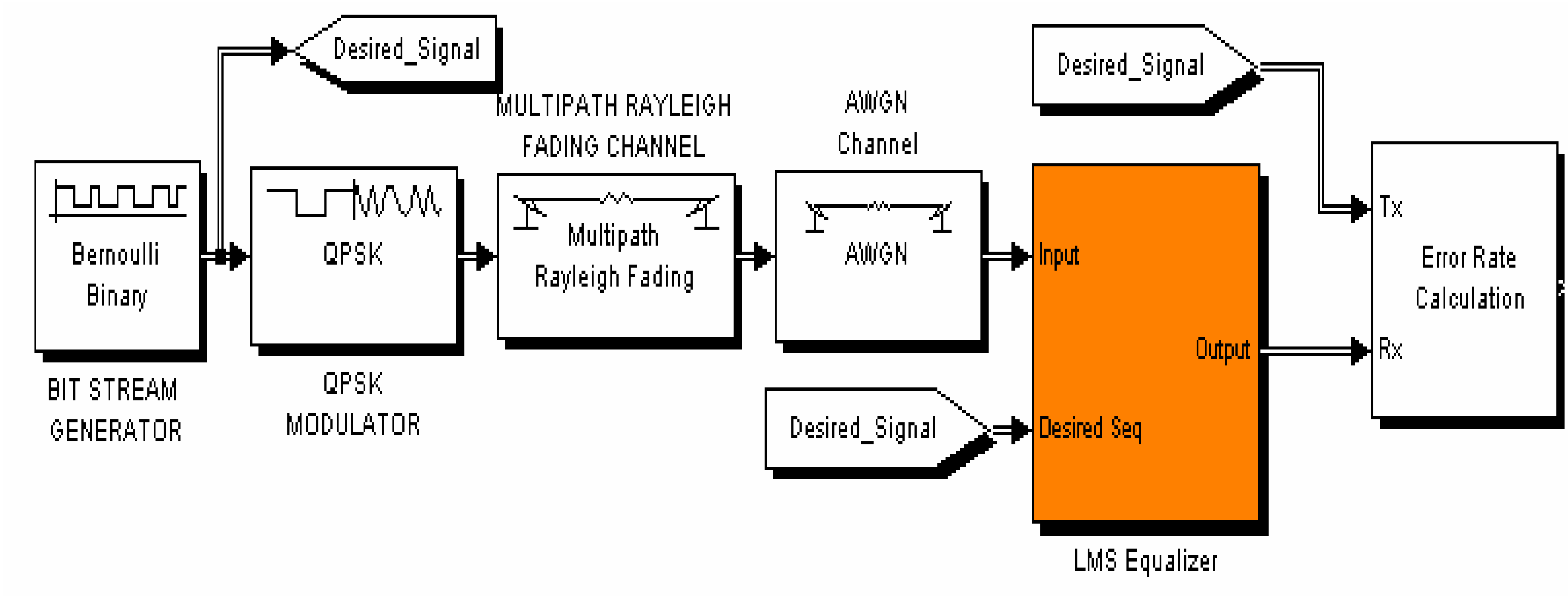
F083-B04-010

LMS Equalizer Model Implementation



F083-B04-010

Validation Model for LMS Equalizer

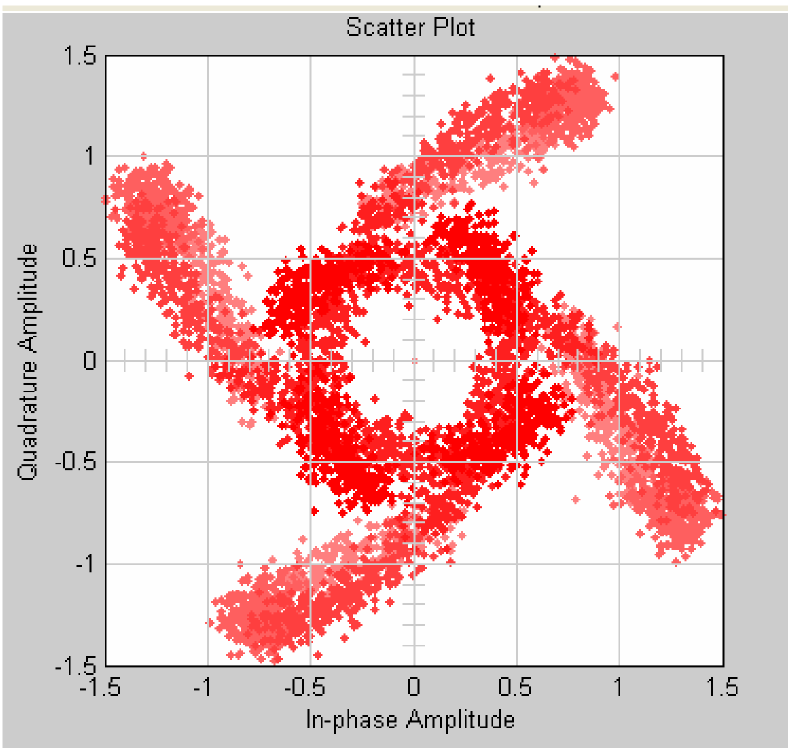


Number of equalizer taps: 6
Step size: 0.03
Number of training bits: 48

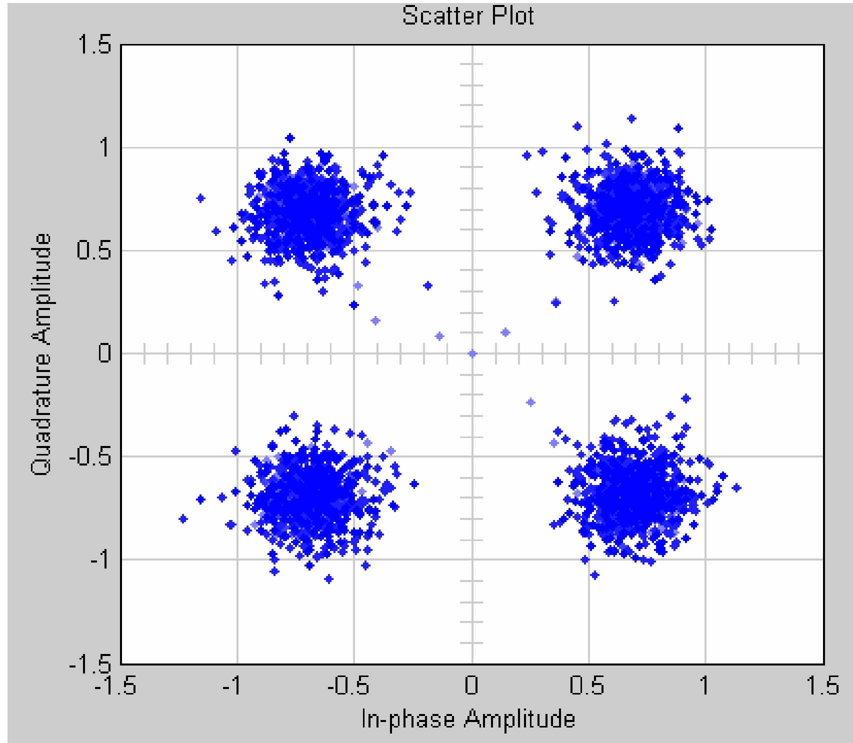
MITRE

CAASD

LMS Equalizer Corrects Doppler and Multipath Impairments

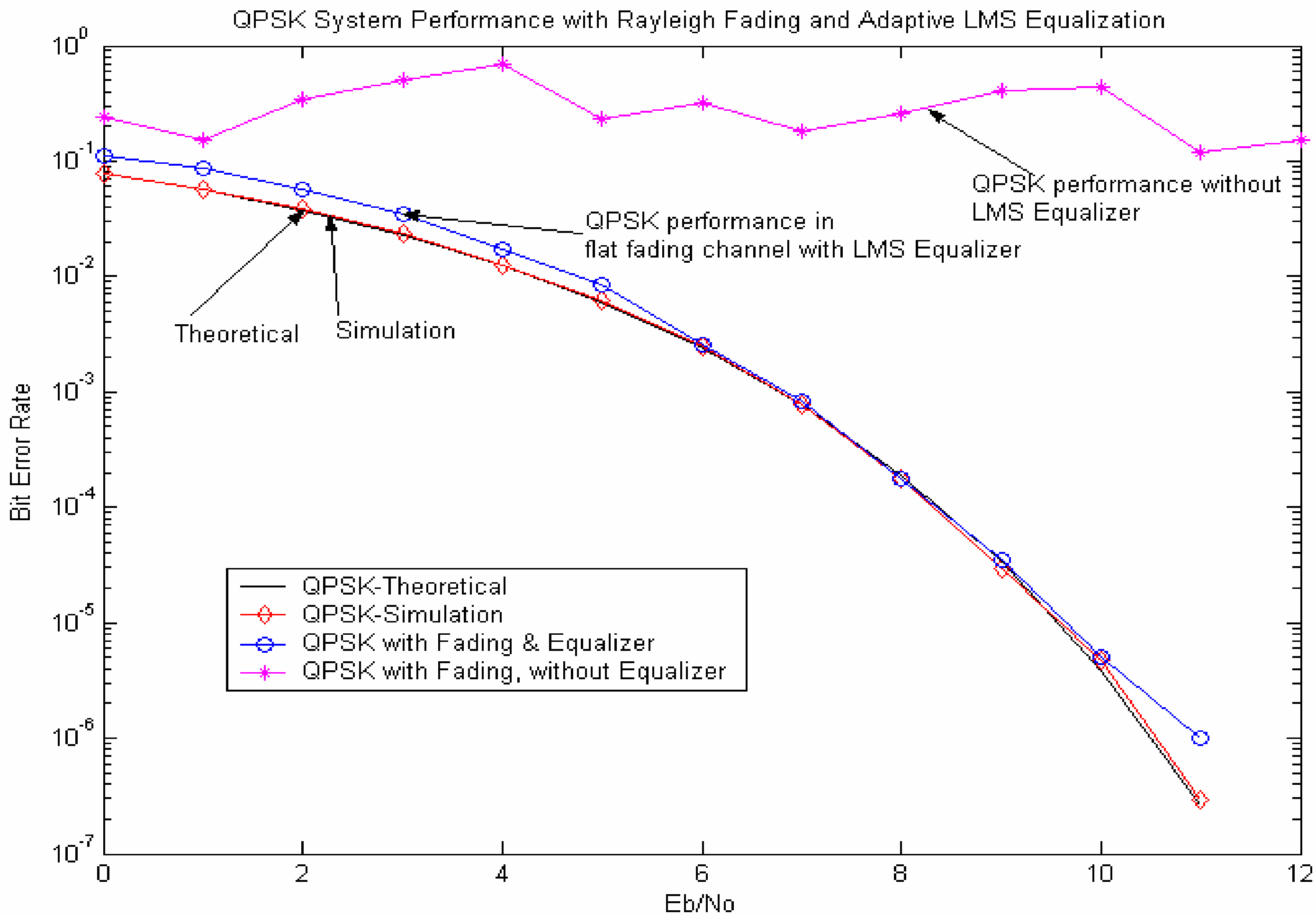


QPSK Signal Constellation Affected by Doppler, Multipath and AWGN



Doppler and Multipath Effects Compensated by the LMS Equalizer

Validation Results for LMS Equalizer

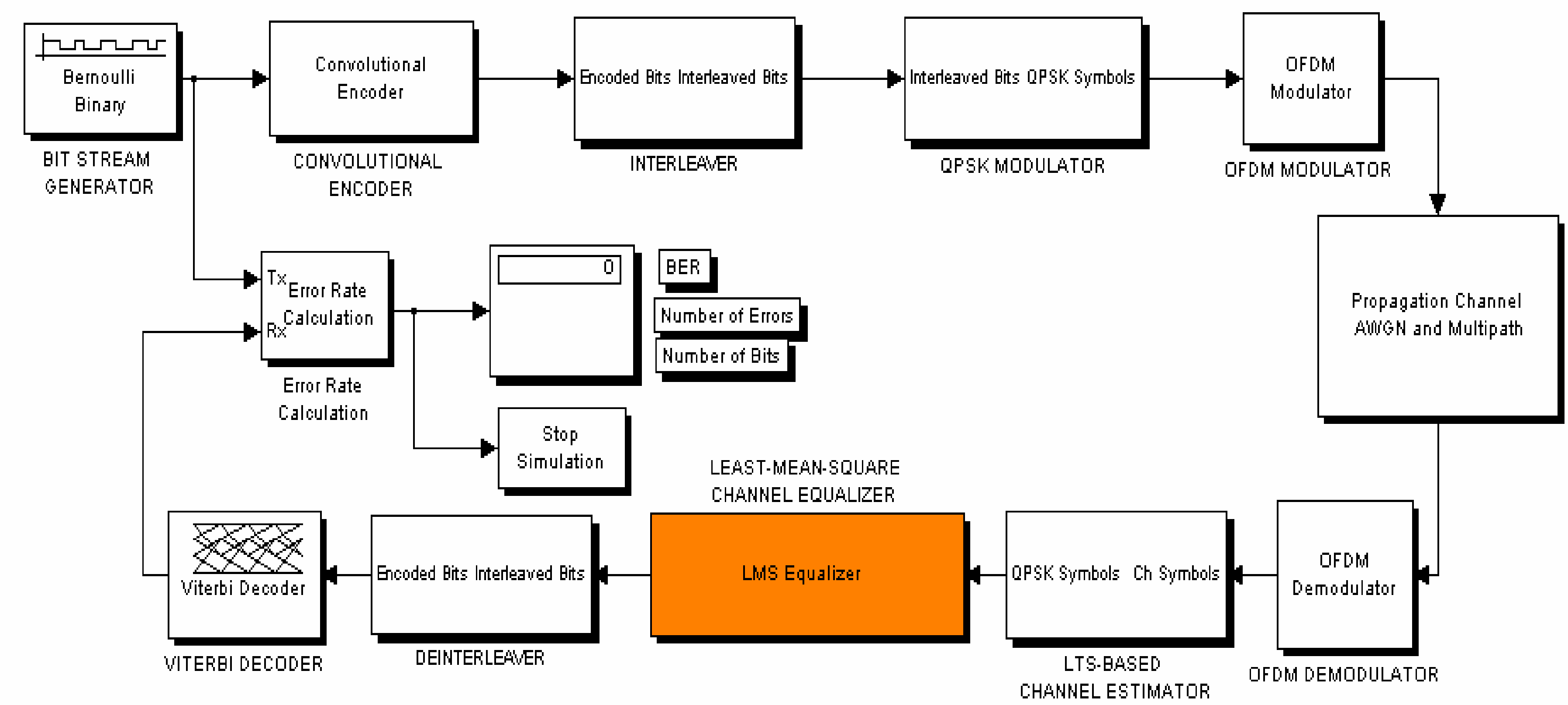


MITRE

CAASD

F083-B04-010

Integration of LMS Equalizer into the IEEE 802.11a Baseline Model

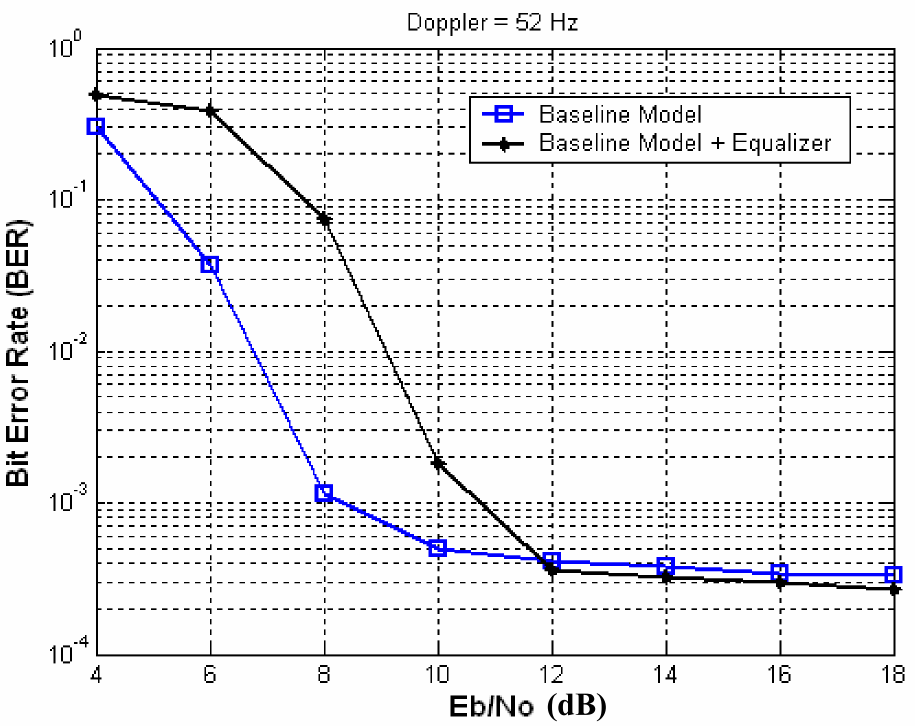


MITRE

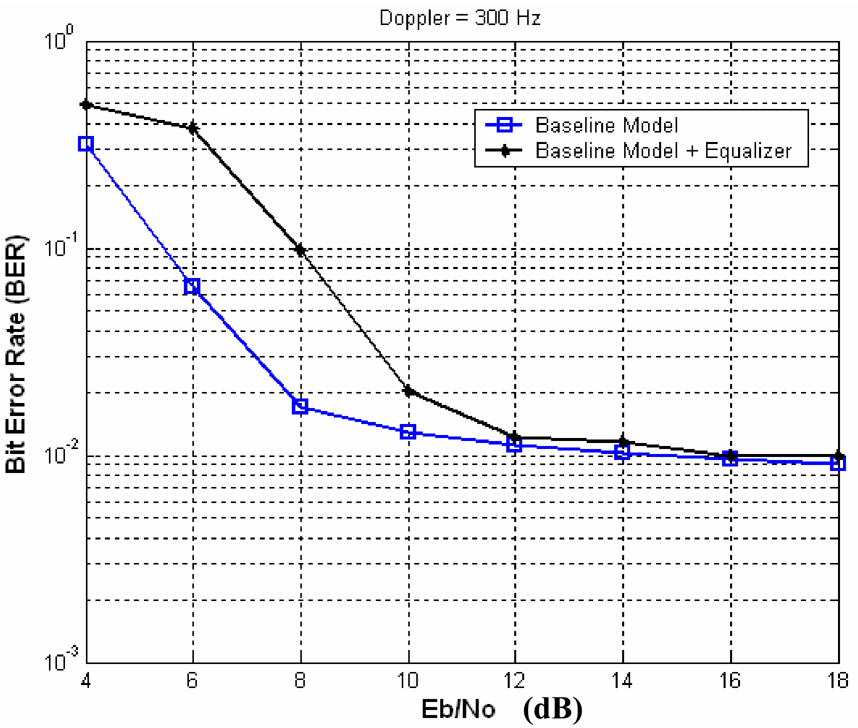
CAASD

F083-B04-010

Preliminary Performance Results



Model Performance at Doppler Shift = 52 Hz (7 miles/hr)



Model Performance at Doppler Shift = 300 Hz (40 miles/hr)

MITRE

CAASD

F083-B04-010

Summary and Lessons Learned

- Summary
  - The Least Mean Square algorithm was implemented in Simulink and added to the baseline model based on IEEE 802.11a 12 Mbps QPSK
  - Preliminary results, under Rayleigh fading, showed 1-2 dB system improvement at the speed of 7 miles/hour (for Eb/No values above 12 dB)
- Lessons Learned
  - Current LMS model did not performed as well as expected
  - Possible improvements on the LMS equalizer:
    - Increase the number of taps of the LMS equalizer so that the equalizer can be more adaptive to the multipath channel
    - Increase the number of training bits with a trade-off of message overhead
  - Evaluate the performances of other more complex adaptive equalization techniques (e.g., recursive least squares or non-linear decision feedback techniques)